Comparison of accelerated T1-weighted whole-brain structural imaging protocols

Pavel Falkovskiy[1,2], Daniel Brenner[3], Thorsten Feiweier[4], Stephan Kannengiesser[4], Bénédicte Maréchal[1,2], Tobias Kober[1,2], Alexis Roche[1,5], Kaely Thostenson[6], Denise Reyes[6], Matthias Seeger[7], Tony Stoecker[3], Matt Bernstein[6], and Gunnar Krueger[1,2]

[1]*Advanced Clinical Imaging Technology, Siemens Healthcare IM BM PI, Lausanne, Switzerland,* [2]*CIBM - AIT, École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland,* [3]*German Center for Neurodegenerative Diseases (DZNE), Bonn, Germany,* [4]*Healthcare Sector, Siemens AG, Erlangen, Germany,* [5]*Department of Radiology, University Hospital (CHUV), Lausanne, Switzerland,* [6]*Department of Radiology, Mayo Clinic, Rochester, Minnesota, United States,* [7]*Laboratory for Probabilistic Machine Learning, École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland*

Intended Audience: Pulse sequence designers and those who use structural brain imaging in clinical research

Introduction

In clinical settings, reduced MRI scan times are desirable for patient throughput, improved patient comfort and better management of patient motion. Recently, several strategies have been proposed to further reduce acquisition time in structural-brain imaging protocols beyond conventional parallel imaging, e.g. 2D-GRAPPA [1], CAIPIRINHA [2] [3], and segmented MPRAGE [4]. This work qualitatively and quantitatively compares the performance of four prototype 3-minute MPRAGE variants with the frequently employed 5-minute ADNI-2 protocol [5].

Materials and Methods

All experiments were performed on a standard clinical 3T MRI (MAGNETOM Skyra, Siemens AG, Erlangen, Germany) equipped with a 32-channel head coil array. 22 healthy subjects were imaged after providing written consent. The measurement protocol consisted of five 3D MPRAGE volume acquisitions (TR/TI= 2300/900 ms, α= 9 deg., 1mm isotropic, BW=240 Hz/pixel): (a) T1w ADNI-2 protocol (TA=5:12 min) [5]; (b) as (a) but using 2D-GRAPPA that accelerates acquisition through undersampling data in both phase and slice encoding directions (TA=2:59 min) [1]; (c) extension of 2D-GRAPPA method with a CAIPIRINHA approach (TA=2:59 min) [2] [3]; (d) 2D-GRAPPA CAIPIRINHA with elliptical scanning (TA=2:40 min) [2] [3]; (e) segmented MPRAGE as proposed recently [4] with 4-fold acceleration based on combining conventional parallel imaging and a two-echo acquisition (BW=480 Hz/pixel, TA=3:15 min). The order of the scans was randomized between sessions. For qualitative analysis, all data were graded by an experienced, blinded image analyst from the ADNI MR Core. Within-session, scans were graded on a 1-5 relative scale (1: best, 5: worst). Grades were averaged across the subjects. Quantitative volumetric measurements of the total intracranial volume (TIV), cortical white matter (cWM), hippocampus and cortical grey matter (cGM) were performed using an in-house algorithm described in [6]. Normalized volumetric differences (D) between the ADNI-2 reference (V_r) and each variant (V_v) were computed for each structure: $D=(V_v-V_r)/(V_r+V_v)$ and averaged across the subjects. For further characterization, voxel-wise SNR quantifications were performed using a prototype inline implementation of the Pseudo-Multiple Replica approach described in [7]. SNR maps were spatially normalized within session to the ADNI-2 image volume. Subsequently, mean SNR values in selected brain structures such as brain stem, hippocampus, cWM and cGM were computed using the masks obtained from segmenting the ADNI-2 datasets.

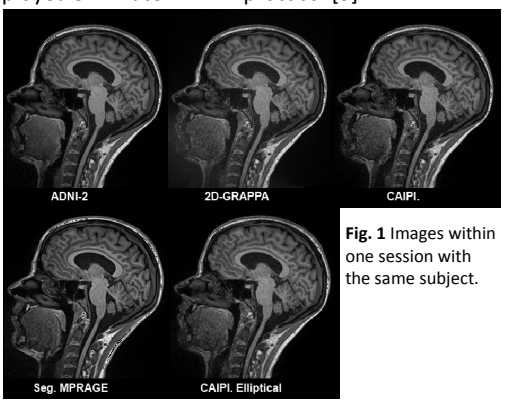

Fig. 1 Images within one session with the same subject.

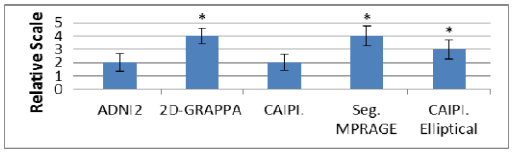

Fig. 2 Observer Rankings. * indicates significant difference from the ADNI-2 median computed using Wilcoxon rank-sum test.

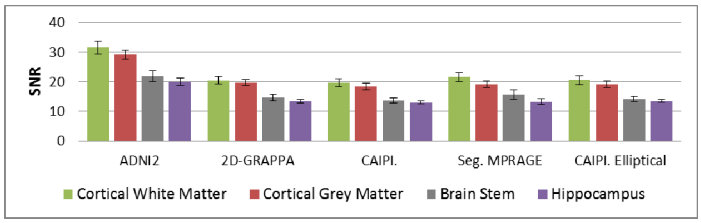

Fig. 3 SNR measurements. Error bars show standard deviations across the subjects.

Results and Discussion

All images were rated by the observer to be of high quality or with mild image quality issues. Qualitative observations yielded that all images provide clinically useful image quality with the expected increase in noise in accelerated acquisitions (Fig. 1). The median observer rankings are shown in Fig. 2. Notably, the 3-minute CAIPIRINHA MPRAGE scans are perceived on average of identical value for reading as the 5-minute ADNI-2 scans, whereas the other protocols appear statistically different ($p < 0.05$). SNR measurements quantitatively confirm the expected SNR loss due to k-space undersampling with 2D-GRAPPA and CAIPIRINHA, and bandwidth increase for segmented MPRAGE. All accelerated acquisitions have similar performance with respect to SNR (Fig. 3). The quantitative volumetric analysis indicates that the acceleration introduces systematic differences to the processing when compared to the reference ADNI-2 MPRAGE (Fig. 4). As such, we observed statistically significant increase in the cWM volumes in the accelerated acquisitions (lower SNR) and a trend towards decreased cGM volumes. These initial investigations suggest that segmentation algorithms may be sensitive to the input CNR, which is also indicated in respective processing carried out using the FreeSurfer software [8]. Such effects could potentially be addressed by correction strategies but require further research in order to pool data from MPRAGE variants. In summary, the investigated acquisitions show good potential to substantially reduce the acquisition time in high resolution MPRAGE scans in particular for clinical routine reading.

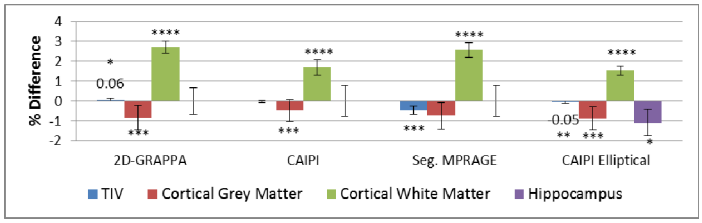

Fig. 4 Volumetric % difference to the MPRAGE reference scan performed using the in-house algorithm. * indicates difference from 0% median at the 5% significance level computed using Wilcoxon signed-rank test. *p~10^{-2}; **p~10^{-3}; ***p~10^{-4}; ****p~ 10^{-5};

References [1] Blaimer et al., 2006, MRM., 56:1359–1364; [2] Breuer et al., 2006, MRM 55:549-56; [3] Brenner et al., 2013, ESMRMB; [4] Falkovskiy et al., 2013, ISMRM; [5] Jack et al., 2010, Alzheimers Dement., 6 (3):212–220; [6] Roche et al., 2011, MIM., 15(6):830-839; [7] Robson et al., 2008, MRM., 60:895–907; [8] Reuter et al., 2012, Neuroimage, 61(4): 1402–1418;

This work was supported by CIBM of the UNIL, UNIGE, HUG, CHUV, EPFL and the Leenaards and Jeantet Foundations